CONTINUOUS AUTOMATIC BEAMHOUSE PROCESSING II. ADAPTATION OF CHEMICAL OPERATIONS TO THE REQUIREMENTS OF THE PROCESS‡

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Abstract

Mathematical relationships are presented which describe the diffusion of salt through hides and the effect of sulfide concentration, ionic strength, and temperature on the rate of hair removal. The applicability of the results obtained to the design and development of the continuous, automated beamhouse process developed at the Eastern Regional Research Center of the U.S. Department of Agriculture is illustrated.

Introduction

The tanning industry has expressed the need for processes which would reduce manual labor, ensure safer working conditions, increase labor productivity, reduce solid and liquid wastes, improve utilization of natural resources, and save process chemicals and energy (1-5). The Engineering Science Laboratory of the Eastern Regional Research Center has designed and built a process which is aimed at meeting many of these objectives. Although this process incorporates some deviations from established practices, special efforts have been made to give the tanning industry flexibility in the choice of operating conditions and to allow it, whenever economically feasible, to duplicate closely, commercial operating conditions.

Process Development and Design

ADAPTATION OF PRESENT COMMERCIAL PROCESSING

Commercial procedures are presently capable of yielding satisfactory leather even from dirty and dry hides. To have this capability necessitates the use of long

processing times since the epidermis and the flesh layer interfere with penetration of water and chemicals to the leathermaking portions of the hide. Nevertheless, the degree of treatment imparted to each hide often varies, causing some variability in the quality of leather obtained. Because of the long and uneven duration of the different processing steps, present commercial procedures were modified in this work and adapted to the requirements of continuous automated operation without adverse effects on leather quality. This was accomplished by removing the hair, epidermis, and flesh as quickly as possible allowing the exposed grain and corium layers to receive more uniform treatment during subsequent processing. To help in rational design, research was conducted to obtain mathematical relationships describing the diffusion of salt through the hide and reaction of the sulfide with hair and epidermis. This paper summarizes the results of this basic research and shows how the data were utilized in the design and development of the continuous automatic beamhouse process.

Description of Automated Process

Figure 1 gives a schematic diagram of the automated beamhouse process developed at ERRC. The process consists essentially of a feeder, a hide sprayer, two vats for soaking, and one vat for unhairing as well as equipment for mechanical unhairing, fleshing, and splitting. The spray removes the surface salt
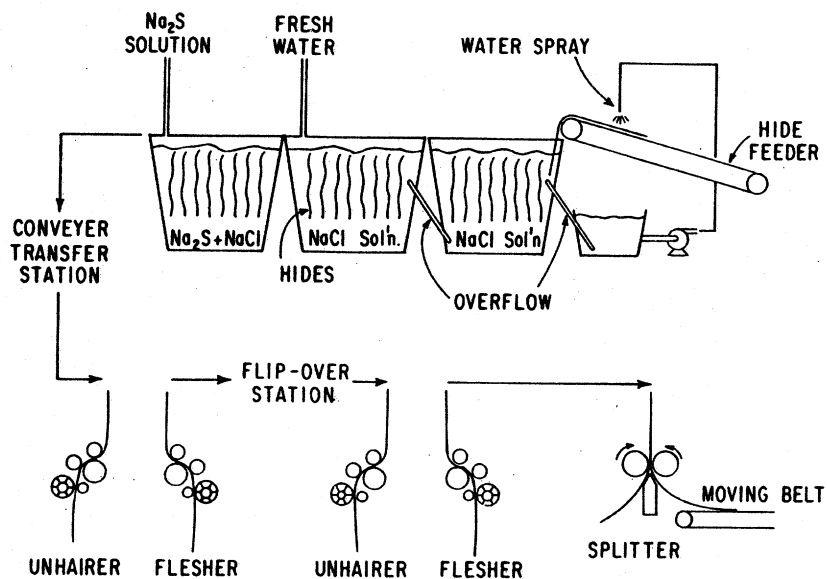

FIGURE 1. — Automated Beamhouse.

from the hides quickly and efficiently. This helps to stabilize the salt concentration in the first vat where additional salt is removed from the hide by diffusion. The rate of salt removal in this vat continues to be fairly high because of the high concentration gradient between the hide (where the salt content on a solvent basis is 36 percent) and the solution in the vat (where the salt content is kept at a predetermineed value of about 10 percent). To continue rapid removal of salt from the hide, the concentration in the second vat is kept at or about 3 percent salt. By introducing fresh water only in the second vat and by letting it overflow from there, first into vat No. 1 and then into the hide spraying system, the amount of water used is minimized. This method of operation in which the water flows countercurrently to the movement of the hides, allows removal of almost half of the salt originally present in the hides in about 20 min. When emerging from the second vat, the hides have little salt in their surface layers; consequently, the amount of salt diffusing out of the hides in the third vat, containing the unhairing solution, is limited. But inside the hides, the salt concentration is still fairly high, and, therefore, the hides exhibit very little swelling during their treatment in the unhairing bath. As in each of the soaking vats, the residence time in the unhairing vat is kept at about 10 min.

Most of the hair is still on the hides as they emerge from the unhairing vat. After being transferred from the low-speed conveyor, which carried the hides through the vats, to a high-speed conveyor, one-half of each hide is mechanically unhaired and fleshed or refleshed in one set of machines consisting of an unhairer and a flesher (see Figure 1). The hides are turned upside-down at the flip-over station, and the other half of each hide is unhaired and fleshed or refleshed in another set of these machines. Finally, the hides are automatically split, yielding a grain split of uniform thickness because the hide is not swollen by the process.

The grain splits are then relimed and processed into leather by conventional batch techniques with some minor adjustments to present commercial processing procedures. This work will be reported in forthcoming papers. The mechanical features of the equipment used in the process are described in detail elsewhere (6).

It is obvious that the aforementioned process is different from any known conventional, commercial operation. The changes introduced were necessitated by the need to minimize costs through synchronization of all processing steps making them as short in duration as possible. This process thus represents a compromise between the constraints imposed by cost and by chemical and mechanical factors.

MECHANICAL DESIGN CRITERIA

In any industrial process which involves several machines operating in series, the slowest machine determines the process rate. Examination of the mechanical aspects of automated beamhouse processing indicated that the slowest operation

would be the hide feeder which can be fed at about 2 hides/min. It was also determined that the distance between hide bars must not be less than 6 in. Thus:

$$\text{Hide processing rate} = \frac{2 \text{ hides}}{\text{min}} \times \frac{8 \text{ hr}}{\text{shift}} \times \frac{60 \text{ min}}{\text{hr}} = 960 \frac{\text{hides}}{\text{shift}},$$

and assuming a 10-min processing time in each vat,

$$\text{length of a vat} = \frac{2 \text{ bars}}{\text{min}} \times \frac{10 \text{ min}}{\text{vat}} \times \frac{0.5 \text{ ft}}{\text{bar}} = 10 \text{ ft/vat}.$$

This is certainly an acceptable vat length for an operation approaching 1,000 hides per shift. Note, however, that if we had assumed a residence time of 5 hr (which is the minimum time used commercially for soaking), the vat length would have been:

$$\text{vat length} = \frac{2 \text{ bars}}{\text{min}} \times \frac{5 \text{ hr}}{\text{vat}} \times \frac{60 \text{ min}}{\text{hr}} \times \frac{0.5 \text{ ft}}{\text{bar}} = 300 \text{ ft/vat}$$

Obviously, a 300-ft vat for just soaking would hardly be practical, especially, if a 10-ft vat could suffice.

Chemical Design Criteria

When one considers the relatively long soaking and unhairing times used commercially, as compared to the 10-min residence times suggested by the above constraints, it is obvious that ways to shorten these processing times must be found. Consequently, detailed research studies were conducted on the desorption of salt from hides and on the kinetics of the reaction between hair and sulfide.

Laboratory Studies on Soaking and Unhairing

Experimental Procedure. To study the rate of diffusion of salt through the hide during soaking, four experiments were conducted in which samples weighing about 1 kg were cut from the bend portion of heavy, prefleshed Black Angus hides. Each of the samples was cut further into three pieces of approximately equal size and contacted with a large quantity of water (2.5 to 4.0 l) in a drum 40 cm in diameter rotating at 10 RPM. The uptake of salt by the water was measured by recording the specific gravity increase of the solution with time over a period of about 18 hr. Analyses were also made of the sodium content in the hide samples and in the solution at the end of the experiment.

To study the rate of unhairing at different concentrations of sodium sulfide, brine cured hide pieces weighing approximately 20 g were equilibrated for about 4 hr with sufficient amounts of water to attain a predetermined salt content. The hide pieces were then wrapped around stainless steel cylinders weighing 180 g, with the flesh side facing the cylinder, and all of the hair exposed. After forming a tuft of hair and firmly clamping it between the jaws of a standard laboratory clamp, 2.25 cm wide, the hide pieces (and the weights) were fully submerged in

about 400 ml of sulfide solution. This solution contained the same ionic strength as the solution in the hide. To provide sufficient agitation, the maximum setting on a Corning PC-353* stirrer, provided with a 1 in. stirring rod, was used. The sodiumn sulfide concentration of the sulfide solutions was varied from 0.63 percent to 6.3 percent (1 percent to 10 percent commercial sodium sulfide. All concentrations of chemicals in this paper are given on a 100 percent basis.) The sodium chloride concentration was varied from zero percent to saturation. An attempt was made to clamp as many hairs as possible. The pull exerted by the stainless steel cylinders simulated the force appolied by the knife cylinder of an unhairing machine. The time at which the tuft of hair broke was arbitrarily defined as the time at which hair can be removed from the hide mechanically. The epidermis was considered to be removable if little force was needed to scrape it off with a spatula. The times required for hair break and epidermis removal at different concentrations of salt and sodium sulfide were recorded.

Experimental Results

Soaking. Typical results on salt diffusion are given in Tables I and II. The data in Table II were obtained on brined hide pieces from which the surface salt

TABLE I
DIFFUSION OF SALT FROM HIDE[1]

Reaction time, hr	Salt concentration in soak water (g/1)	W (g)	M_t (g)	$\dfrac{M_t}{M_\infty}$
.033	24.41	63.5	41.2	.288
.083	26.50	68.8	46.5	.325
.125	27.54	71.5	49.2	.344
.208	29.69	77.0	54.7	.383
.375	32.74	84.0	61.7	.432
.875	36.91	96.0	73.7	.516
1.667	45.35	117.0	94.7	.663
18.0	63.56	165.2	142.9	1.00

[1] 1040 g brined hide contacted with 2.6 l water. Calculations corrected for crystalline salt and the fractional uptake of salt by solution.
M_t = amount of salt which has left the hide at time, t.
W = total weight of NaCl in soak water (g).
M_t = W – S, where S = weight of undissolved, crystalline salt present on the hide and estimated to be equal to 22.3 g by combing and scraping another piece from the same hide.
M_∞ = amount of salt which has left the hide after infinite time.

had been combed and scraped off. No attempt was made to remove salt from the hide pieces in the experiment reported in Table I. The data are presented in

*Reference to brand or firm name does not contitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.
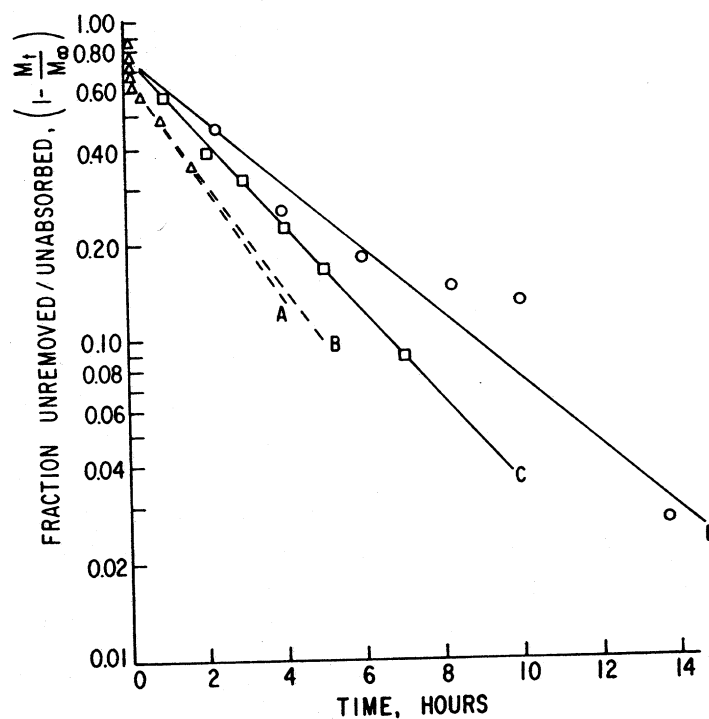
FIGURE 2. — Diffusion of salt through hide. Plot of fraction of salt unremoved during soaking (lines A and B) and fraction of salt unabsorbed during commercial curing (lines C and D) vs time in hr.

TABLE II

DIFFUSION OF SALT FROM HIDE[1]

Reaction time, hr	Salt concentration in soak water (g/1)	M_t (g)	$\dfrac{M_t}{M_\infty}$
.017	5.6	19.6	.145
.042	8.9	31.2	.231
.083	11.21	39.2	.291
.125	12.36	43.3	.321
.208	14.83	51.9	.385
.375	16.64	58.2	.432
.875	20.76	72.7	.538
1.667	24.55	85.9	.637
2.333	28.18	98.6	.731
20.667	38.56	135.0	

[1]998 g hide contacted with 3.5 l of water. (Hide scraped free of salt prior to soaking.) Same definitions of terms as in Table I except that no correction had to be made for surface salt. Thus, S = 0 and M_t = W.

Figure 2 as plots of the logarithm of the fraction of salt unremoved, log $(1 - M_t/M_\infty)$, vs time, t; where M_t = total amount of salt which has left the hide at time t, and M_∞ is the corresponding quantity after infinite time. These plots (lines A and B) are compared to similar plots (lines C and D) of recently published data (7, 8) obtained during commercial brine curing of hides. From the published data, the ordinate in Figure 3 gives the fraction of salt unabsorbed by the hide at time t. Using the slopes of the lines and the equation for the unsteady-state diffusion from an infinite slab (9), the effective diffusivity D of salt per unit thickness of hide (L) squared was calculated. Values of (D/L^2) equal to 4.97 $\times 10^{-5}$ sec^{-1} and 4.47 $\times 10^{-5}$ sec $^{-1}$ were obtained for the soaking experiments, and 2.97 $\times$ 10^{-5} sec^{-1} and 2.35 $\times$ 10^{-5} sec^{-1} from the published brine curing data.
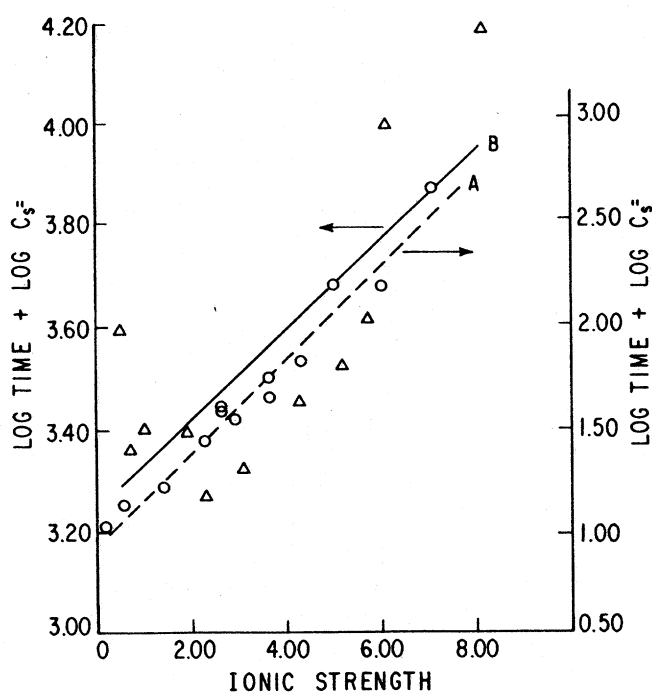

FIGURE 3. — Dependence of hair and epidermis removal on time, t, in seconds, ionic strength, I, and sulfide concentration, $C_{s=}$ in M/1. Room temperature. Equation of line A for hair removal (circles): $\log t + \log C_{s=} = 0.938 + 0.220$ I. (R-Square = 0.963, Res. error = 0.0088, and max. deviation = 0.133.) Equation of line B for epidermis removal (triangles): $\log t + \log C_{s=} = 3.24 + 0.0870$ I. (R-Square = 0.583, Res. error = 0.0389, and max. deviation = 0.583.)

The thickness of the pieces used was 0.380 cm and diffusion is known to take place almost entirely from the flesh side; hence, the diffusivity of salt through the hide during soaking was calculated to be 7.20×10^{-6} cm^2/sec and 6.02×10^{-6} cm^2/sec from lines A and B of Figure 3, respectively.

The diffusivity of salt in water is equal to 1.36×10^{-5} cm^2/sec at 17% salt content (10). From experimental data, the moisture content of brined hides increases from approximately 43% to 67% during soaking (the average being 55%). Assuming that the diffusion of salt occurs primarily across the voids occupied by water (the solid material represents a hindrance to diffusion), the effective diffusivity of sodium chloride from a prefleshed brined hide can be calculated to be:

$$D = 0.55 \ (1.36 \times 10^{-5})$$

$$= 7.48 \times 10^{-6} \ \text{cm}^2/\text{sec}.$$

This calculated value is in good agreement with the above experimental results for soaking. The slightly lower diffusivities obtained during commercial brine curing are probably due to insufficient mixing of the brine solutions in the raceways. The fact that the diffusivities in commercial brined hides are close to those obtained here, provides some assurance that during soaking most hides can be expected to behave as predicted by theory.

Unhairing. The data on the removal of hair and epidermis are given in Tables III and IV and in Figure 3 as plots of the sum of log t and $C_{s=}$ vs the ionic strength of the reaction solution.

TABLE III
REACTION TIME TO REMOVE HAIR

Na$_2$S (%)	Sulfide ion conc. $C_{s=}$* m/l	NaCl (%)	Ionic strength I	Reaction time, t (sec)	Log t + log $C_{s=}$
6.2	0.483	0	2.30	56	1.43
6.2	0.483	2	2.64	82	1.59
6.2	0.483	4	2.98	70	1.53
6.2	0.483	8	3.67	110	1.72
6.2	0.483	12	4.35	135	1.80
6.2	0.483	16	5.03	308	2.17
6.2	0.483	22	6.06	300	2.16
6.2	0.483	28	7.08	900	2.63
.62	.0175	0	0.23	619	1.03
.62	.0175	3.5	0.60	766	1.13
.62	.0175	8	1.45	920	1.21
.62	.0175	15	2.64	2101	1.57
.62	.0175	22	3.67	2445	1.63

*$C_{s=}$ calculated by using an equilibrium constant for the dissociation of sulfide equal to 5×10^{-14} (which is an average of the values found in the literature).

TABLE IV
REACTION TIME TO REMOVE EPIDERMIS

Na_2S (%)	Sulfide ion conc., $C_{s=}$* m/l	NaCl %	Ionic strength I	Time, t (sec)	Log t + log $C_{s=}$
6.20	0.483	5	3.08	4341	3.32
6.20	0.483	12	4.27	5848	3.45
6.20	0.483	17	5.18	6902	3.52
6.20	0.483	20	5.72	8492	3.61
6.20	0.483	22	6.09	20277	3.99
6.02	0.483	34	8.09	31117	4.18
6.20	0.483	0	2.3	3899	3.27
4.96	0.366	0	1.9	6699	3.39
2.48	0.147	0	1.0	17219	3.40
1.86	0.0978	0	.7	23496	3.36
1.24	.0545	0	.5	70958	3.59

*Calculated by using an equilibrium constant for the dissociation of sulfide equal to 5×10^{-14}.

Here t = reaction time in seconds to either break the hair or to remove the epidermis, and

$C_{s=}$ = sulfide ion concentration in moles/1.

Reference to Figure 3, line A, gives the following expression which was found experimentally to predict the reaction time needed to render hair removable as a function of sulfide ion concentration and ionic strength:

$$\log(t) = 0.938 - \log C_{s=} + 0.220I, \tag{1}$$
where I = ionic strength.

Similarly, Figure 3, line B, shows that the reaction time needed to render the epidermis removable can be calculated from the following equation:

$$\log(t) = 3.24 - \log C_{s=} + 0.0870I \tag{2}$$

The effect of temperature on the reaction rate can be seen from a plot of log time against 1/T (Figure 4), where T is the absolute temperature in °K. The activation energy calculated from the slope of the straight line in Figure 4 is 10.2 kcal/mole. This indicates that during unhairing diffusion is probably the rate controlling mechanism. The activation energies for processes controlled by diffusion within solids usually range between 10-14 kcal/mole while values of 4-5 kcal/mole are usually reported for the diffusion of solutes in water (11).

Equations (1) and (2) can be written in the following general form:

$$t = \frac{K_1 F(I)}{C_{s=}} \tag{3}$$

where F(I) = a function of the ionic strength of the solution, I, and K_1 = constant.
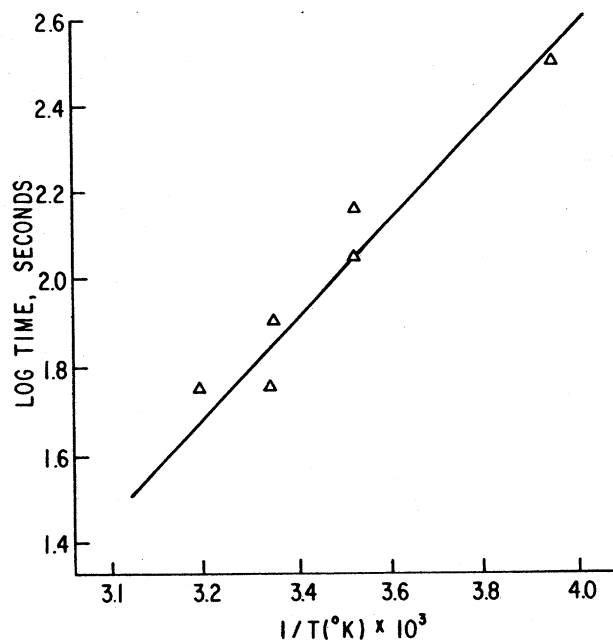
FIGURE 4. — Calculation of activation energy for unhairing process. Unhairing conducted in a 6 percent sodium sulfide solution.

Activation energy = Slope of line × 2.30 × R.

= 10.2 kcal/mole.

Time given in sec and T in °K. (R-Square = 0.966, Res. error = 0.006, and max. deviation = 0.103.)

Herrmann (11) has also found diffusion to be the rate-limiting step in reactions between keratin and mercaptans, while King (12) asserts that diffusion inside single fibers becomes the dominant factor when drying materials as dense as wool.

It is interesting that eq. (3) can be deduced from the following equation which is applicable to diffusion-controlled heterogeneous reactions inside solid cylinders immersed in an unlimited amount of solution (13):

$$t = \frac{\varrho_\beta \, R^2}{4DC_{s=}} \left\{ 1 + \left(\frac{R_c}{R}\right)^2 \quad [2 \, \ln \left(\frac{R_c}{R}\right) - 1] \right\} , \tag{4}$$

where t = time

ϱ_β = no. disulfide bonds per unit volume

D = diffusion coefficient.

$C_{s=}$ = sulfide ion concentration
R = radius of hair (cylinder)
R_c = radius of advancing boundary

For complete reaction of the hair fiber, which occurs when $R_c = 0$, eq. (4) reduces to:

$$t = \frac{\varrho_\beta R^2}{4DC_{s=}} \tag{5}$$

The terms ϱ_β, R, and D are average values which may be considered constant in this study; thus eq. (5) becomes:

$$t = \frac{K_1}{C_{s=}}. \tag{6}$$

Comparison of eqs. (3) and (6) shows that they are of the same form except for the term $F(I)$. At low salt contents, however, this term can be ignored. The density of hair is equal to 1.3 g/cm^3 (12), the concentration of cystine in the hair is about 500 μ moles/g, and the number of disulfide bonds is about 10 mole percent; hence, the disulfide bond density is:

$$\varrho_\beta \sim 500 \frac{\mu M}{g} \times \frac{M}{10^6 \mu M} \times \frac{10 \text{ disulfide bonds}}{100 \text{ moles}} \times 1.3 \cdot \frac{g}{cm^3}$$

or

$$\varrho_\beta \sim 6.50 \times 10^{-5} \text{ disulfide bonds per } cm^3.$$

Since

$$D \sim 10^{-8} \; cm^2/sec \; (11)$$

$$R \sim 18\mu \times \frac{10^{-4} \; cm}{\mu} = 1.8 \times 10^{-3} \; cm \; (14),$$

and, moreover, a 1 percent sodium sufide solution has a sulfide ion concentration of about 1.3×10^{-5} moles/cm^3, eq. (4) gives for the unhairing time:

$$t = \frac{6.5 \times 10^{-5} (1.8 \times 10^{-3})^2}{(4)(10^{-8})(1.3 \times 10^{-5})} = 6.75 \text{ min.}$$

This result compares reasonably well with the value of 10 min obtained from eq. (1), considering the approximate values used for D, and the inconsistencies encountered in the literature with regard to the equilibrium constant for dissociation of sulfide (which is considered to be equal to 10^{-13} in some textbooks and 10^{-14} in others).

Equations (1) and (2) show that the unhairing rate decreases hyperbolically with an increase in salt content. Shimizu and Oku (15) and McPhee (16) have

also observed a decrease in the reaction rate between wool and alkali with an increase in salt content. Danehy (17) and Feairheller et al. (18) believe that the first step in unhairing involves a reaction with the hydroxyl ion. The mathematical evidence of this work supports either a physical hindrance to diffusion (caused by the effect of the high ionic strength on the hair protein) or a decrease in activity of the reacting hydroxyl or sulfide ions with an increase in ionic strength.

Application of Experimental Data to Process Design

Soaking. To explore the possibility that countercurrent leaching using several soaking stages might sufficiently decrease the total contact time for soaking, calculations were made by utilizing the experimental value for $D/L^2 = 4.7 \times 10^{-5}$ sec^{-1} and by assuming different numbers of soaking stages and various salt concentrations in the hides and in the solutions leaving the system after contact. It is permissible to use an algebraic eq. (9) for calculating the number of ideal countercurrent stages needed. Knowledge of the diffusion coefficient then allows calculation of the Murphree stage efficiency (9) which, when divided into the number of ideal stages, yields the number of actual stages required. Some of the calculated data are given in Table V. As can be seen from line 1 of this Table, a

TABLE V
#### SOAKING OF PREFLESHED SALTED HIDES USING DIFFERENT NUMBERS OF PROCESSING STAGES

Fresh water input or float (%)	No. of stages	Time per stage (min)	Total soak time (min)	NaCl Out		
				With hide		With effluent
				Hide wt. basis (%)	Solvent basis (%)	Solvent basis (%)
100	1	∞	∞	4.4	9.7	9.7
100	1	180	180	4.3	9.5	9.8
100	4	10	40	4.0	9.0	11.1
100	5	5	25	4.4	9.7	9.7
100	6.6	3	20	4.4	9.7	9.7
100	1	∞	∞	4.4	9.7	9.7
250	2	10	20	4.4	9.7	3.8
78	2	10	20	7.0	15.5	9.0
41	2	10	20	9.5	21.0	11.1

one-stage batch operation with brined hides and 100 percent float should yield (after an infinite length of soaking time) about 9.7 g of salt per 100 g of water, both in and outside the hide, which corresponds to about 4.4 g salt per 100 g of hide on hide weight basis. Line 2 shows that almost the same results are obtained

after 3 hr or 180 min of soaking. The next three lines show that the total soaking time varies inversely to the number of soaking stages used if the water consumption and the salt content in the hide remain constant. The last three lines show that, conversely, the water consumption varies inversely as the salt content in the hide if the total soaking time and the number of soaking stages are kept constant. Observe that comparison of lines 6 and 7 of the Table show that it should be possible to remove the amount of salt usually removed during commercial overnight soaking by utilizing two 10-ft vats with a 10 min residence time each if the water consumption is increased to 250 percent. Furthermore, the last line shows that under the operating conditions previously discussed in the mechanical design section (involving 10-min operations in 10-ft vats), water consumption can be reduced to 41 percent if a 9.5 percent salt content on hide weight basis, or a 21 percent salt content on solvent basis can be tolerated, for example, in the removal of hair or epidermis.

Unhairing. Using eqs. (1) and (2), plots of time vs salt concentration for different sodium sulfide contents in solution were prepared; these are shown in Figure 5. These plots show that the reaction time for epidermis removal, represented by the dashed lines, is much longer than the reaction time needed to remove the hair, represented by the solid lines. The rectangular area in this Figure is presented in Figure 6, which shows that a hide containing 9.7 g NaCl per 100 g water, (i.e., a hide with a salt content often found inside commercially soaked hides) can be mechanically unhaired after 5 min in a 3 percent Na_2S solution. The epidermis needs 90 min in a sulfide solution as high as 6 percent to
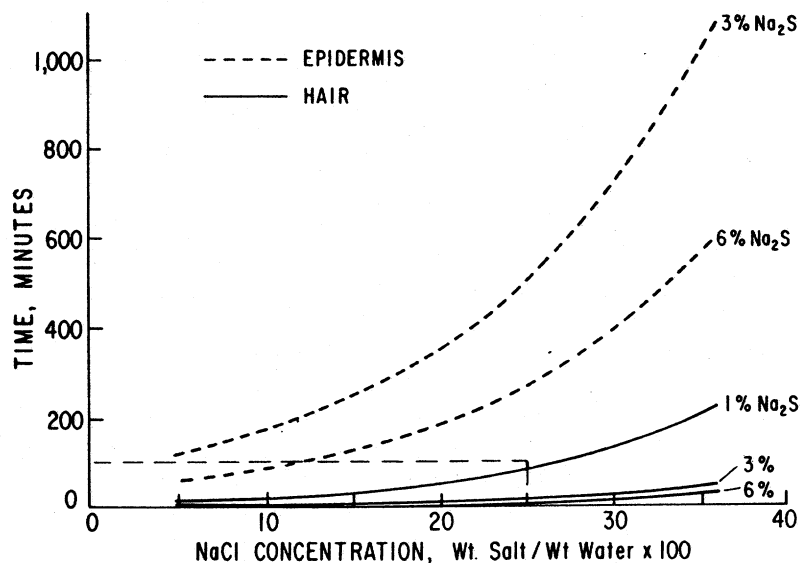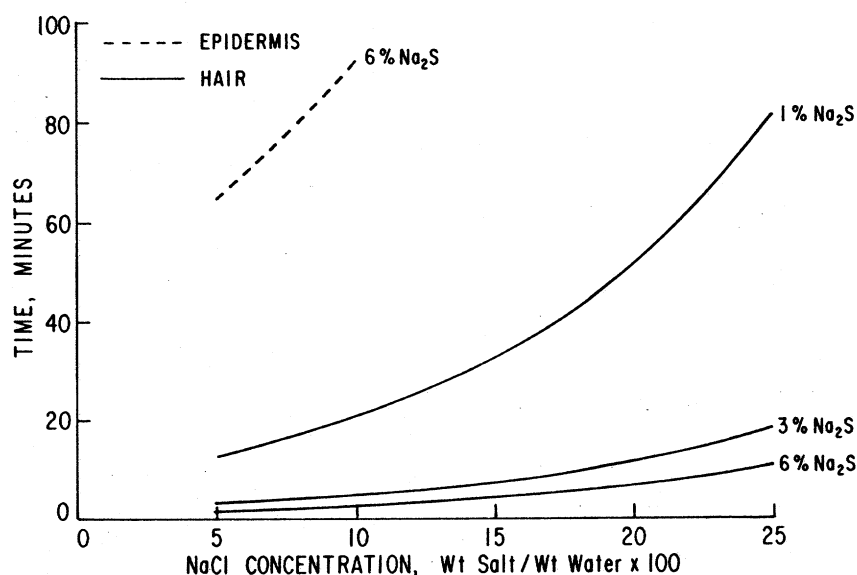
FIGURES 5   Time to render hair and epidermis removable at different concentrations of salt
AND 6. —   and sulfide [calculated using eqs. (1) and (2)].

become removable by mechanical action such as scraping, rubbing, or machine unhairing. This assumes that the salt content in the hair is the same as in the hide. Moreover, a 90-min unhairing time would require a vat 18 times longer than that required for a 5-min unhairing time; consequently, it was decided that automated beamhouse processing should be designed to remove only the hair prior to splitting.

OTHER DESIGN FACTORS

While the desire to duplicate commercial leather quality is a primary goal in the design, it is also felt that because of environmental concerns, some modification of the processing conditions is worthwhile to reduce the volume of liquid effluent and to obtain a grain split of more uniform thickness. Experimentally, it was observed that hides containing about 21 g NaCl per 100 g water, or 9.5 percent on hide weight basis, have the following desirable characteristics: they do not swell readily on exposure to sulfide solutions, they are manipulable, and they split to a uniform thickness (19). Furthermore, hides of this salt concentration can be obtained by using only 41 lb of water per 100 lb of hide in a continuous, countercurrent process using two stages with a 10-min residence time in each stage, as was pointed out previously. By substituting appropriate values for the thickness of hide and hair, and for the diffusivity of sodium chloride in them, into diffusion equations for infinite slabs and cylinders (20), respectively, it was

calculated that the hair looses sodium chloride during soaking at about the same rate as the hide. Therefore, it can be seen by extrapolation using Figure 6 that such a hide can be unhaired in 10 min in a 4-5 percent sodium sulfide solution assuming the salt to be uniformly distributed throughout the hair. Having been attained under dynamic conditions of soaking by countercurrent flow in as short a time as 20 min, the salt distribution inside the hair as well as inside the hide is not uniform. Most of the salt is in the center portions of the hide and very little can be found in the outer layers. Consequently, the sodium chloride concentration in the unhairing bath attained after prolonged operation (i.e., under steady-state conditions) is not 21 percent but in the range of 7-10 percent.

Summary and Discussion

In summary, based on the mechanical and chemical, considerations discussed above, the design and construction of the process includes a 10-min residence time in each of two soaking vats and in one unhairing vat, and reduction of the salt content in the hides from 36 g to 21 g NaCl per 100 g water (or from 14 percent to 9.5 percent on hide weight basis). Approximately 4.5 percent sodium sulfide solution can be used to render the hair removable in an unhairing machine. The water consumption during soaking is as low as 41 lb per 100 lb of hide. Proper control of the percentage of sodium sulfide in the solution added to the unhairing vat during processing results in no liquid effluent except the sulfide leaving with the hide.

It should be clear from the research findings that this process also permits considerable variation in the operating conditions. For example, by varying the rate of water input to the second soaking vat, the degree of salt removal from the hide can be varied over a wide range, and variation of the conveyor speed permits increase and decrease in the residence time.

It can be argued that this process falls short of accurately duplicating commercial operating conditions. For example: in commercial practice soaking is carried out not only to remove salt but also to remove soluble noncollagen proteins and mucoids from the hide. While this is definitely true, there is also ample information in the literature (21) to show that these soluble materials will be readily removed during later processing steps. Therefore, any shortcoming inherent in the automated process should be correctable by adjustment of the operating conditions of the subsequent processing steps.

The wet blue stock made to date from the hides processed in the automated beamhouse revealed no visual defects or mechanical weaknesses which could be attributed to the process.

The Engineering Science Laboratory is currently engaged in exploring the range of operating conditions, on a pilot plant scale, which yield acceptable leather and in identifying the best operating conditions from the standpoint of leather quality.

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